



# Forest Health Protection

## Pacific Southwest Region

### Northeastern California Shared Service Area

Date: December 2, 2011

File Code: 3420

To: District Rangers, Beckwourth Ranger District, Plumas National Forest and Yuba River Ranger District, Tahoe National Forest

Subject: Insect and Disease Evaluation of the Lakes Basin Recreation Area (FHP Report NE11-18)

At the request of Geoffrey Kaeberle and Terri Walsh, Silviculturists, Beckwourth Ranger District and Yuba River Ranger District, I conducted a field evaluation of the Lakes Basin Recreation Area on September 30, 2011. The objective of this visit was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss treatment alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density and increasing resiliency to disturbance events such as drought, fire, insects and diseases. Geoff Kaeberle, Janice Sangunitto and Terri Walsh accompanied me in the field.

### **Background**

The Lakes Basin Recreation Area (LBRA) is located south of the town of Graeagle, CA at elevations ranging between 4800 and 6800 feet (39° 42' 37.36"N and 120° 39' 11.72"W) with annual precipitation between 40 and 80 inches. Forested areas range from mixed conifer at lower elevations, consisting of white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), Douglas-fir (*Pseudotsuga menziesii*), Jeffrey pine (*Pinus jeffreyi*) and incense cedar (*Calocedrus decurrens*), to red fir (*Abies magnifica*), western white pine (*Pinus monticola*) and lodgepole pine (*Pinus contorta* var. *murrayana*) types at higher elevations. Deciduous hardwoods such as black cottonwood (*Populus trichocarpa*), quaking aspen (*Populus tremuloides*), alder (*Alnus* sp.) and Scouler's willow (*Salix scouleriana*) are also found throughout the project area. Most stands are densely stocked, contain high levels of dead-down material and are experiencing elevated levels of tree mortality associated with insects and pathogens.

The management objectives for the LBRA are to increase forest resiliency through mechanical thinning and prescribed fire. Treatments will first be implemented in and around campgrounds and administrative sites and then progress into areas that have road access. Prescribed fire will be the primary tool for treating stands in inaccessible areas.

---

Danny Cluck  
Forest Entomologist  
530-252-6431  
dcluck@fs.fed.us

Bill Woodruff  
Plant Pathologist  
530-252-6880  
wwoodruff@fs.fed.us

In many areas, a variable thinning strategy will be used to reduce stand density and change species composition to a more sustainable condition. Sanitation thinning will occur along roads and within recreation sites to reduce the number of hazard trees as well as stand density. Other thinning treatments may focus on hardwood enhancement, visual enhancement around lakes or improving wildlife habitat. The thinning will reduce density to 45% to 60% of SDI maximum, varying by stand type (approximately SDI 220 to 300). This will result in a residual basal area average from 80-150 square feet per acre. The residual stands will be more open, increasing the amount of available soil moisture and sunlight for individual trees.

### **Forest insect and disease conditions**

Note: Due to the large size of the project area, all observations of stand conditions and associated insect and disease activity were made from main roads. Many potential treatment areas were not thoroughly inspected and significant insect and disease issues may exist that were not captured during this evaluation.

#### **Dwarf mistletoes**

Dwarf mistletoes were observed on several tree species within the LBRA. Many trees that were heavily infected showed signs of reduce vigor such as thinning crowns and branch flagging.

- White fir dwarf mistletoe (*Arceuthobium abietinum* f. sp. *concoloris*) was observed along the Packer Lake Road in overstory and understory white fir causing deformity, branch flagging and possibly contributing to mortality.
- Western dwarf mistletoe (*Arceuthobium campylopodum*) was observed in Jeffrey pine throughout the project area. A few locations had many heavily infested trees and elevated levels of mortality.
- Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) has infected lodgepole pines in stands along Gold Lake Highway causing bole and limb swellings, brooming and reduced vigor as indicated by thinning crowns.
- Many red fir at the higher elevations have high levels of dwarf mistletoe (*Arceuthobium abietinum* f.sp. *magnificae*) combined with cytospora canker (*Cytospora abietis*) infections (Figure ?????).

#### **Bark beetles**

Bark beetle activity was observed on nearly all conifer species causing significant tree mortality in some locations.

- Mountain pine beetle (*Dendroctonus ponderosae*) caused mortality of lodgepole pine was observed in high elevation stands and along Packer Creek. Mountain pine beetle was also observed in western white pine (Figure ??).
- Jeffrey pine beetle (*Dendroctonus jeffreyi*) has caused the mortality of many large diameter Jeffrey pine over the last few years and is continuing to attack individuals and small groups of all larger size classes (figure ???).
- High levels of white fir mortality caused by the fir engraver beetle (*Scolytus ventralis*) can be found throughout the LBRA. Especially high levels of mortality are occurring south of the Packer Lake Road (Figure ???).

Other pathogens

- Heterobasidion root disease (*Heterobasidion occidentale*s, formerly referred to as S-type annosus root disease) centers in red fir were observed near the ??? camp as indicated by the presence conks in old stumps. Windthrown trees near the entrance to this same camp also had delaminated decay that may be associated with *H. occidentale*s.
- White pine blister rust (*Cronartium ribicola*) was observed in western white pine causing branch flagging and top-kill.
- Elytroderma needle cast (*Elytroderma deformans*) was observed on a few Jeffrey pines.

**Stand conditions and mortality related to recent and future climate trends**

Many of the forested areas in the LBRA appear to be at or above “normal” stocking levels and in drier years exhibit an elevated level of tree mortality caused by bark beetles. This mortality combined with high stand density has resulted in heavy fuel loading in many areas. MAP and table

Many stands appear to be experiencing major species composition shifts to more shade intolerant species. Jeffrey pine was likely the dominant species in most low to mid elevation stands before the fire suppression era. White fir, and in some cases, lodgepole pine has increased in relative abundance and increasing competition for limited resources. This has resulted in the loss of larger diameter Jeffrey pines to bark beetle attacks and a lack of Jeffrey pine regeneration due to heavily shaded stand conditions. Drier Jeffrey pine - white fir stands are experiencing high levels of mortality of both species.

White fir mortality increased during 2007 - 2009 throughout northeastern California as a result of drier than normal conditions. For example, the Palmer Hydrological Drought Index (PHDI) for Sierra Cascade Division, which encompasses the LBRA, registered moderate drought conditions each year for 2007 – 2009 (Table 1). A return to normal to above normal precipitation in 2010 and 2011 has reduced moisture stress for all conifer species and reduced the current level of tree mortality.

**Table 1. Palmer Hydrological Drought Index (PHDI) 2007 - 2010, Water Year (Oct-Sept), California Division 2 (Sierra Cascade)**

YEAR	PHDI
2007	-2.61
2008	-2.92
2009	-2.52
2010	0.53
2011	2.40

\*PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

White fir that succumb to fir engraver beetle attacks are typically predisposed by other factors that compromise their health and vigor. In the LBRA, high stand density (in some areas), prolonged drought, dwarf mistletoe and heterobasidion root disease are all contributing factors in declining tree health. The LBRA’s average annual precipitation of 40 - 80” put white fir at a low risk to mortality without factoring in stand density and disease (D. Schultz 1994, FHP Report 94-2). Yet with this much precipitation, white fir mortality remains high.

Predicted climate change is likely to impact trees growing in this stand over the next 100 years. Although no Plumas/Tahoe National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests and ;;;;;;;;;;;;;;*). The risk of bark beetle caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

Western white pine is also exhibiting limited regenerating due to several factors such as shading and competition from true fir and the build up of duff and litter on the forest floor.

### **Considerations for thinning treatments**

#### **Management Alternatives**

**Do nothing:** The no management alternative would allow the older and more decadent Jeffrey, western white and lodgepole pines and true firs, growing under dense stand conditions, to eventually succumb to bark beetle attacks. Dwarf mistletoe infections will likely expand in range and intensify within currently infested stands, further reducing tree health and vigor. Stand density will continue to increase over time, consisting mostly of small diameter red fir and white fir. Occasionally high levels of tree mortality are likely to occur, for all size classes and species, during extended periods of below normal precipitation. Western white and Jeffrey pine will occupy an even smaller percentage of the stands due to limited regeneration and mortality of mature trees. Over time, this trend will result in stands that are more densely stocked with smaller diameter trees and that have extremely heavy fuel loads. Fuel loads will continue to increase creating a higher risk of high intensity and stand replacing fire across all forest types. Although stand replacing fires may not be ecologically destructive to the red fir and lodgepole stands (all longer fire return interval forest types), it will likely be devastating in terms of tree mortality and subsequent regeneration for any Jeffrey pine - white fir stands (shorter fire return interval forest types). These areas will likely become shrub fields for many years after such an event.

Most of the forested portions of both the CW and the TLW are typical for drier western coniferous forests and lodgepole pine forests that have had fire excluded for 100+ years. These stands all share common characteristics such as high accumulations of fuels, dense understories made up of mostly shade tolerant species, such as red and white fir, mortality occurring from insects and disease, primarily in the larger trees, and limited regeneration of mostly shade intolerant tree species such as lodgepole pine, western white pine, ponderosa and Jeffrey pine.

The thinning prescriptions for the LBRA should be consistent with past direction from the Regional Forester to thin to “ensure that density does not exceed an upper limit (for example: 90%

of normal basal area, or 60% of maximum stand density index)” and to “design thinnings to ensure that this level will not be reached again for at least 20 years after thinning.” (Regional Forester letter, “Conifer Forest Density Management for Multiple Objectives”, July 14, 2004). This treatment should effectively reduce inter-tree competition for limited water and nutrients and reduce the risk of insect and disease caused mortality for most areas. The exception to this is the drier southwest facing upper slopes which may require more extensive thinning to achieve appropriate stocking levels.

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines, should benefit by having the stocking around them reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees. This type of ecological restoration approach would also be consistent with the Region 5 Ecological Restoration Strategic Priority.

When implementing thinning projects, retaining more drought tolerant species such as Jeffrey pine, Douglas-fir and incense cedar over white fir will increase species diversity and make stands more resilient to disturbance. This is especially true in areas where Jeffrey pine is heavily encroached with white fir. Significantly reducing the amount of white fir in these areas provide more opportunities for Jeffrey pine regeneration and substantially reduce present and future fuels loads created by dead and dying white fir. In addition, when selecting trees for removal, preference should be given to trees heavily infected with dwarf mistletoe, root disease and trees infested with bark beetles. Small group selections could be utilized to remove white fir that are within known heterobasidion root disease centers and/or are heavily infected with dwarf mistletoe. This would create openings that could be planted with non-host species.

It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14” in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity. In recreation areas, all conifer stumps >3” in diameter should be treated.

Western white pine and sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. Planting openings created by any group selection harvest with rust resistant stock would help insure this species persists in the area.

Scouler’s willow (*Salix scouleriana*), a shade intolerant species, is present within the stand and is being overtopped by competing conifers (mostly white fir and incense cedar) resulting in the decline and mortality of individual clumps. To preserve and enhance the growing conditions for this hardwood species, some areas should be thinned heavier around these shrubs.

### **Considerations for prescribed fire**

Few vegetation management options are available to land managers for wilderness areas. Building roads and carrying out timber stand improvement and thinning activities are not permitted. Cutting trees and other vegetation is only allowed under special circumstances such as fire, insect and disease outbreaks (mainly for controlling exotic invasive species) or when protecting public safety.

Prescribed fire may be used to alter forest structure but it is critical to know something about the historic stand structure and fire regime in order to best apply this management tool.

**Rx Fire:** Consideration should be given to developing a long-term prescribed and natural fire use plan, if not already in place, to strategically return fire as a natural ecosystem process. Many of the insect and disease related issues found in these wilderness areas are a result of a general homogenizing of tree ages (most trees now in older age classes) and overstocked stand conditions in the absence of fire. Historically, low, moderate and high severity fires occurred relatively frequently within the wilderness areas, regenerating stands and selecting for more pine dominated forests (Bekker and Taylor 2000, Taylor and Solem 2001).

If restoring a natural fire regime in the wilderness areas is a management goal, fires will need to be within their historic range of variability in terms of acreage burned and intensity. Taylor and Solem (2001) found the average fire extent in the CW to be approximately 375 acres burning at mostly moderate intensity. Bekker and Taylor (2000) found the average fire in the TLW to be approximately 750 acres mostly burning at moderate to high intensity. They also describe historic fires in the lodgepole forest of the TLW as averaging 1000 acres in size with most of the area burning at moderate to high intensity. Clearly, any moderate or high intensity fire occurring within the CW or the TLW will have a high probability spreading to adjacent non-wilderness lands. Therefore, these adjacent lands will need to have sufficient, large scale fuel reduction treatments completed in order to significantly reduce fire intensity and facilitate fire suppression efforts.

Light underburning, which is the typical prescription for most controlled burns, cannot be expected to promote the regeneration of lodgepole pine on a historic scale and may actually reduce its presence within treated stands. Most lodgepole, which have very thin bark, will likely be killed during low intensity fires but the medium to large red fir present in the stand will not. This not only favors the retention of true fir but it also does not consume the fuel and open up the stand to the degree necessary to promote large amounts of lodgepole regeneration. The shaded environment will likely persist and continue to favor true fir regeneration. This result was observed in a prescribed underburn area in the southern portion of the CW.

For ponderosa pine – white fir and Jeffrey pine – white fir forest types, prescribed fire alone under dense stand conditions may cause excessive tree mortality and actually increase the amount of fuels post fire. Dense understories of small trees serve as ladder fuels and can carry fire up into the crowns of overstory trees. If there is any possibility of thinning and removing understory trees and reducing dead fuels in the Jeffrey pine – white fir stands, especially in the TLW, it should be considered before fire is reintroduced. In a nearby fire history study in Lassen Volcanic National Park, Taylor (2000) also suggested that managers should consider physical manipulation of fuels before reintroducing fire into Jeffrey pine and Jeffrey pine – white fir forests in order to minimize mortality of large diameter trees.

Mature pines, including sugar and western white pines, are also especially susceptible to mortality during prescribed burns because of the deep duff and litter that accumulates at their base. These duff mounds typically burn at a slow rate, while maintaining lethal temperatures, causing severe cambium injury. Cambium injury was observed on western white pine in the prescribed underburn in the southern portion of the CW. For this reason, it may be beneficial to rake the duff away from the bases of large pines before burning.

Western white pine and sugar pine should be protected as much as possible during any prescribed burning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created by prescribed or wildland fire with rust resistant stock would help insure this species persists in the area.

If prescribed fire is used as a follow-up treatment to stand thinning, unacceptable levels of large diameter pine mortality may occur depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature Jeffrey, ponderosa and especially sugar pines are susceptible to mortality during prescribed burns because of the deep duff and litter that has accumulated at their base in the absence of fire. These duff mounds typically burn at a slow rate, while maintaining lethal temperatures, causing severe cambium injury. To protect individual large diameter pine from lethal cambium injury, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

### **Hazard Trees**

Hazard trees are present along most trails, around trailhead parking areas and around most primitive campsites. These trees are either standing snags or green trees with major structural defects.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

*/s/ Danny Cluck*

Daniel R. Cluck  
Forest Entomologist  
NE CA Shared Services Area

cc: Geoffrey Kaeberly, District Silviculturist, Beckwourth RD  
Terri Walsh, District Silviculturist, Yuba River RD  
Janice Sangunitto, Silviculturist, Beckwourth RD  
Ryan Tompkins, Forest Silviculturist, Plumas SO  
Mark Brown, Forest Silviculturist, Tahoe SO  
Forest Health Protection, Regional Office

## **Appendix A – Insect and Disease Information**

### **Jeffrey Pine Beetle**

The Jeffrey pine beetle is the principle bark beetle found attacking Jeffrey pine, which is its only host. It is a native insect occurring from southwestern Oregon southward through California and western Nevada to northern Mexico. The beetle normally breeds in slow-growing, stressed trees. The beetles prefer trees which are large, mature, and occur singly rather than in groups. Yet when an epidemic occurs, the beetle may attack and kill groups of trees greater than 8 inches in diameter, regardless of age or vigor. Often the beetle infests lightning-struck or wind-thrown trees, but does not breed in slash.

#### **Evidence of Attack**

Presence of the beetle is usually detected when the foliage changes color. The color change of the foliage is related to the destruction of the cambium layer by the beetle. Generally, the top of the crown begins to fade in a slow sequence, with the needles turning from greenish yellow, to sorrel, and finally to reddish brown. By the time the tree is reddish brown, the beetles have usually abandoned the tree. Another sign of beetle attack is large, reddish pitch tubes projecting from the bark of the infested tree. If examined carefully, pitch tubes can be detected on infested green trees prior to crown fade. Jeffrey pine beetles have a distinctive "J" shape egg gallery pattern on the inner bark. Larval mines extend across the grain and end in open, oval-shaped pupal cells.

#### **Life Stages and Development**

The Jeffrey pine beetle is one of the larger pine bark beetles in California. The beetle has a 4 life stages, egg, larva, pupa, and adult. The adults are stout, cylindrical, black, and approximately five-sixteenths of an inch long when mature. The egg is oval and pearly-white. The larva is white, legless, and has a yellow head. The pupa is also white but is slightly smaller than the mature larva. The life cycle is normally completed in one year in the northern part of the range, but in the southern part, two generations per year may occur. The principle period of attack is in June and July, but attacks also are frequent in late September and early October. Similar to other Dendroctonus species, Jeffrey pine beetles use pheromones that attract other beetles to a tree, causing a mass attack that tends to overcome the tree's natural resistance. Blue stain fungi are associated with Jeffrey pine beetle attacks and aid in overcoming the tree's defenses.

#### **Conditions Affecting Outbreaks**

Normally the Jeffrey pine beetle is kept in check by its natural enemies, climatic factors and the resistance of its host. Similar to other Dendroctonus species, the availability of suitable host material is a key factor influencing outbreaks. Healthy trees ordinarily produce abundant amounts of resin, which pitches out attacking beetles. When deprived of moisture, or stressed by other factors such as disease or fire injury, trees cannot produce sufficient resin flow and become susceptible to successful beetle attacks.

### **Mountain pine beetle**

The mountain pine beetle, *Dendroctonus ponderosae*, attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

#### **Evidence of Attack**

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

### **Life Stages and Development**

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

### **Conditions Affecting Outbreaks**

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

## **Fir Engraver**

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater than 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

### **Evidence of Attack**

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle

galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

### **Life Stages and Development**

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

### **Conditions Affecting Outbreaks**

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

## **Heterobasidion Root Disease**

*Heterobasidion spp.* is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface

colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species:

*Heterobasidion occidentale* (also called the 'S' type) and *H. irregularis* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregularis* ('P' type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* ('S' type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

## **Dwarf Mistletoe**

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occasionally vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

## **White pine blister rust**

White pine blister rust is caused by Cronartium ribicola an obligate parasite that attacks 5-needled pines and several species of Ribes spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on Ribes spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to Ribes spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other Ribes spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on Ribes spp. leaves in the fall. Teliospores germinate in place to produce spores (sporidia) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to Ribes spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes spp., its spread from Ribes spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.